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# TECHNIQUES DEALING WITH LOCAL AREA NETWORKS (LAN) BANDWIDTH LIMITATIONS

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| 13. ABSTRACT (Maximum 200 words)<br>This report describes various techniques used for network management and frequency allocation. Modern techniques such as packet switching, data compression, and spread spectrum are explained. The United States Department of Defense involvement in this area is covered as well as areas for future growth. | | | |
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## INTRODUCTION

The objective of data communications is to allow any two (or more) devices to transmit and receive data through some media. Communication networks provide the means for such data transfer. One type of communication network, a Local Area Network (LAN), connects users within a small area such as an office or a building. Local Area Networks connect a group of devices physically through hardwiring. Most LANs today have the same bandwidth as those of 10 to 15 yrs ago. In that same time period, the speed of computers, number of users, and the size of files have increased a hundredfold. Another growing trend is to obtain wireless access to existing wired LANs which puts additional demands on LANs. These LANs are accessed remotely using radio frequency (RF) and infrared (IR) signals. Due to these trends of increasing globalization and rapid development, congestion in the network infrastructure and electromagnetic spectrum has become a serious problem. Thus, much effort has gone into the development of network management and frequency allocation techniques.

With communication resources limited, special techniques must be applied to optimize LAN capacity. To meet existing and future demands, there is an urgent need to promote the use of newer and more effective network management technologies. This report will discuss some of the modern techniques used and areas that still have room for growth.

## DISCUSSION

### Principles of Communication

When dealing with communications, we must concern ourselves with two types of signals, *analog* (continuous-time) signals and *digital* (discrete-time) signals. When two computers communicate, the basic system (fig. 1) consists of transmitting and receiving computers, conversion devices, and a communication channel in between. The communication channel comes in two forms: guided and unguided. With the guided channel, data is sent along a physical path such as coaxial cable, optical fiber, or twisted wire pair. With the unguided channel, data is sent through air, vacuum, or water. This is known as wireless communications.

For long distance transmissions, the most commonly used form of communication channel is the telephone network. One of the limitations of the telephone network is that it is not capable of transmitting digital data because it was designed for voice transmissions which was the only requirement back in the 1960s. Since the signal outputs from a computer are in digital form, something must be done to them before they can be transmitted via the network. Thus, the advent of the modem. The purpose of the modem, whose name is an acronym for modulator/demodulator, is to convert the digital signal from a computer to an analog signal and modulate it at some carrier frequency. This frequency modulated signal is then transmitted via the communication network. The modem at the receiving end demodulates the signal so that the original signal can be extracted and passed on the receiving computer.

## Local Area Networks

Local Area Networks are typically serial systems, so multiple signals have to be sent along the same line, unlike computer busses which have parallel ports allowing dedicated signal paths for each signal. Since LANs do not have this luxury, signal contention problems frequently arise. These problems become more severe as demand for network use grows.

Local Area Networks are generally characterized by three main elements: transmission medium, topology, and the technique used to share access to the transmission medium. Local Area Networks are broken down into two classifications: baseband and broadband. With baseband networks, digital signals are sent along the entire bandwidth of the medium in short bursts of time. The disadvantage of this type of network is that one signal occupies the entire bandwidth allowing only one signal to be transmitted at any given time. The other disadvantage is limitation in distance, since signals at higher frequencies can have significant attenuation. The advantage of baseband is its simplicity and lower cost. Also, since the potential transmission rate of the data can be millions of bits per second, this type of network is still effective and commonly used.

A broadband network, on the other hand, splits the network bandwidth into multiple independent channels. The strength of the broadband system is its tremendous capacity. All of these channels may be in use at any given time allowing multiple signals to be transmitted simultaneously. Multiplexing techniques are commonly used to split the network by combining multiple input signals and sending them along a single communication link. One common form of multiplexing is known as frequency division multiplexing (FDM) which splits the frequency spectrum into multiple frequency channels. Other multiplexing techniques such as time division multiplexing (TDM) can also be used in conjunction with FDM to further divide the network. Time division multiplexing uses the channels created by FDM and incorporates timesharing of three different users on each channel.

### Topology

In order to understand the LAN structure and design, one must understand the different topologies, or network configurations. The various topologies are as follows:

- bus
- ring
- star
- tree

They are graphically shown in figure 2. Though each has its own applications, bus and ring topologies are the most common. It may be interesting to note that the ring structure stands out from the others with one discerning characteristic. All of the nodes are connected serially. Thus if one node goes bad, the entire network goes down.

Once the LAN design is completed, the next step would be to "network" the LANs themselves through what is known as WANs or Wide Area Networks. Though WANs are not a topic of this report, they are basically long-haul networks using telephone lines for communication without limitations in distance.

## Network Management Techniques

### Circuit Switching

Due to the expense of network resources and the recent explosion in demand, use of network management techniques, which are used to make more efficient use of the network resources, have become an integral part of any LAN design. An example of this is circuit switching, which is defined as a technique to connect any two locations by switching a set of physical facilities into place on demand. Circuit switching, in its most basic form, is very limited because there is no signal error detection, no recovery in the event of failure, and data can only be sent to the two end points of the circuit.

A more sophisticated form of switching is known as *store and forward switching* . This method relies on some form of intelligence in the network to store, examine, and forward the message to the destination. The network would consist of computer-controlled switching nodes permanently connected and having the responsibility to move data around. They would have the intelligence to retransmit corrupted data and deal with other failures. Store and forward switching is broken down into two subcategories: message switching and packet switching. *Message switching* consists of storing and forwarding of whole messages. With this method, each computer at a network node is forced to store entire messages before transmitting to the next node. This results in reduced efficiency of the network since significant disk space and processing time is needed at each node. An example of this type of application is electronic mail. Packet switching eliminates these problems, which is why it is extremely popular among network designers.

### Packet Switching

Packet switching is a technique developed in the early 1970s in which any message sent through the network must be first broken into pieces, called packets, of 2,000 bits or less. After transmission, the packets are reassembled to form the complete data set. A packet would consist of a portion of the desired data signal and some address information. A network would consist of a collection of switching circuits and a control system which would switch a set of circuits to set up a communication path between the source and destination.

When a call is made, the control system finds a route over which a set of circuits are available and initiates the necessary switching action. The packet enters the network system through a switching node. The node takes the data and chooses the routing to the next appropriate node. The system selectively routes message segments rather than dedicating communication channels between the transmitter and receiver. Thus the system would have many packets

traveling different routes and headed to the same destination. One potential problem with this method is that data can arrive at the receiver out of order. When the call is finished, all of the network nodes are cleared and available for other calls.

There are two approaches to packet switching. The one just described is known as *datagram*. The other is known as *virtual circuit*. Virtual circuit was developed to solve the problem of data arriving at the receiver out of sequence. With this technique, the path is established prior to transmission of data. The same path is not used for all of the packets, but the paths are laid out ahead of time. This technique is basically a tradeoff between a dedicated system and the datagram. It is more popular than datagram. Overall, both packet switching methods are significantly more efficient than the dedicated system.

Although packet switching can be effective in dealing with all sizes of data, short duration, low content data can be handled more economically. It is ideally suited for applications such as electronic funds transfer (EFT) and teletex messages. Overall, packet switching offers better use of network resources, more flexibility, and better data integrity.

Both approaches of packet switching require a protocol system. Protocols are a set of governing rules established by the International Telegraph and Telephone Consultative Committee (CCITT). The CCITT deals with two aspects of this technology, particularly the protocol for the interface between the transmitter and the network and the protocol between two switching nodes.

### Data Compression

Data compression is a method used to increase the effective signal throughput rate by reducing the number of bits that are required to be sent across the communication channel. This technique results in increased data transmission and speed due to reduction in the quantity of data. The added benefit of this technique is data security. The compressed data would be difficult to interpret without knowing the compression technique. This feature makes data compression especially popular with the defense industry.

Two common compression techniques are *run-length encoding* and *Huffman encoding*. Run-length encoding looks at the data for a repetitive pattern. If the data has a repetitive pattern, it would be replaced by one occurrence of the data pattern and a counter. This is very effective for data streams which have large numbers of repeated patterns such as:

- Computer-generated report text or computer screen images that consist largely of blank characters
- Program source code which contain many blank characters or repeating digits
- Financial data which contain many blank characters or repeating digits

Data compression is usually not effective on word-processing text files and program object code files.

Huffman encoding applies a different approach. It looks at the bit patterns that are used to represent computer character sets. It searches for the most frequently transmitted characters in the message, removes their conventional bit patterns, and applies a new bit pattern which is shorter. This results in the need to give the less frequently transmitted characters a longer bit pattern. Thus, the overall bit transmission is reduced. This technique can result in up to a 50% reduction in data. A more sophisticated form of Huffman encoding can go a step beyond and look at the type of data being transmitted. For example, ASCII text will have a different character frequency distribution than program object code, or a financial database, or a facsimile image (ref 1). This will result in a greater reduction of the data rate.

A lot of work has gone into the development of algorithms for encoding schemes. Some sophisticated algorithms go so far as to provide the ability to change the encoding scheme as the characteristics of the data being transmitted change. Work in this area has been on-going and still has significant room for growth.

## Frequency Management Techniques

### Spread Spectrum

The other side of network management is frequency management. The electromagnetic spectrum has now become the scarcest and most vital resource in the communications industry. Various techniques were developed to maximize the use of this resource. Spread spectrum (SS), one such technique first developed by the military as a deterrent to jamming and espionage, has proven to be effective in dealing with spectrum limitation problems, particularly media contention problems. In SS operation, a transmitted signal is spread across a great bandwidth, with the use of a spreading algorithm. The result is a signal that is essentially "buried" in the noise floor of the radio band and can coexist with narrowband signals. The power distribution of the spread signal as opposed to the narrowband signal is shown in figure 3. The receiver is programmed to examine the bandwidth of the spread signal and correlate the data (despread it).

Spread spectrum signals are designed to provide negligible interference to the communications of the other users, making it difficult to determine if a signal is actually present. The SS signal can coexist with narrowband signals, only adding slightly to the power level of the noise which the narrowband receivers can't detect. As for the spread spectrum receiver, it does not detect the narrowband signals because it is listening to a much wider bandwidth. There are several different types of spread spectrum techniques which are discussed in the following paragraphs.

### Direct Sequence SS

This is probably the most popular technique because it is relatively easy to use. Direct sequence technique simply spreads the signal by modulating it based on a prescribed code

sequence. The receiver converts the wideband signal into its original narrowband signal by the despreading operation. While despreading the desired signal, it spreads any interfering narrowband signals. This reduces the power of the interfering signals and provides overall system performance improvement.

### Frequency Hopping SS

In frequency hopping systems, the carrier frequency repeatedly changes (or hops) from one frequency to another. The hopping pattern is normally determined by the transmitter as dictated by a pseudorandom noise (PN) code.

### Time Hopping SS

A time hopping system is one in which the period and duty cycle of the RF carrier is varied in a pseudorandum manner. Time hopping is commonly used in conjunction with a frequency hopping system to create a Time Division Multiple Access (TDMA) system.

The common denominator of many of these techniques is that they apply a pseudorandum code to each transmitted signal. The signals are differentiated based on their unique PN codes which would be known only by the transmitter and receiver. The advantage of these codes is that they allow multiple signals to be transmitted at the same time and frequency. Hence, multiple users with different codes can share the same channel without interference.

Aside from the obvious benefit of increased spectrum capability, these techniques provide a large degree of privacy compared to other conventional communications systems. In addition, the probability of detection is low because it is difficult to determine if the signal is present. When the intelligent content of the signal is spread over a wide frequency bandwidth, its power is also spread out. This makes detection, without the code, very difficult.

## Department of Defense

The incorporation of the latest techniques and devices into the development of networks is on-going. Many organizations are involved in these efforts. The United States Department of Defense (DoD) is one such organization that has been active in the development of communication networks for many years. The most well known example of this is the Advance Research Projects Agency Network (ARPANET) program. ARPANET was an attempt to interconnect computers at various government organizations, defense contractors, and universities. ARPANET pioneered many of the advanced communications concepts that are currently in commercial use in the world, including the concept of packet switching (ref 1). As opposed to waiting for industry standards to be established, the DoD developed its own communication standards in what is known as DoD Protocol Architecture (DPA). The File Transfer Protocol (FTP) currently used in the government to transfer files between different servers, is the ARPANET FTP.

## CONCLUSIONS

Network management and frequency allocations have become one of the major concerns within the communications industry worldwide. This is due to the overwhelming growth in demand for network access in recent years with more growth expected. Technology must keep pace with the demand. Several state-of-the-art technologies such as packet switching, data compression, and spread spectrum have been developed and implemented with success. But research in this area must continue, particularly with data compression. Data compression is not effective in dealing with word-processing text. This is an area where more sophisticated algorithms must be written to deal with this type of data.

The Department of Defense (DoD) is an active participant in the development of network technologies and has made significant contributions. The DoD has much to gain from further developments in this area. Also, both DoD and industry can benefit from working together and developing common protocol standards.

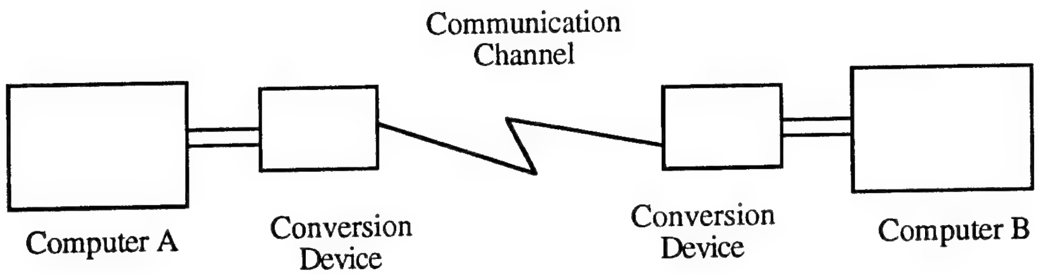


Figure 1
Basic communication system

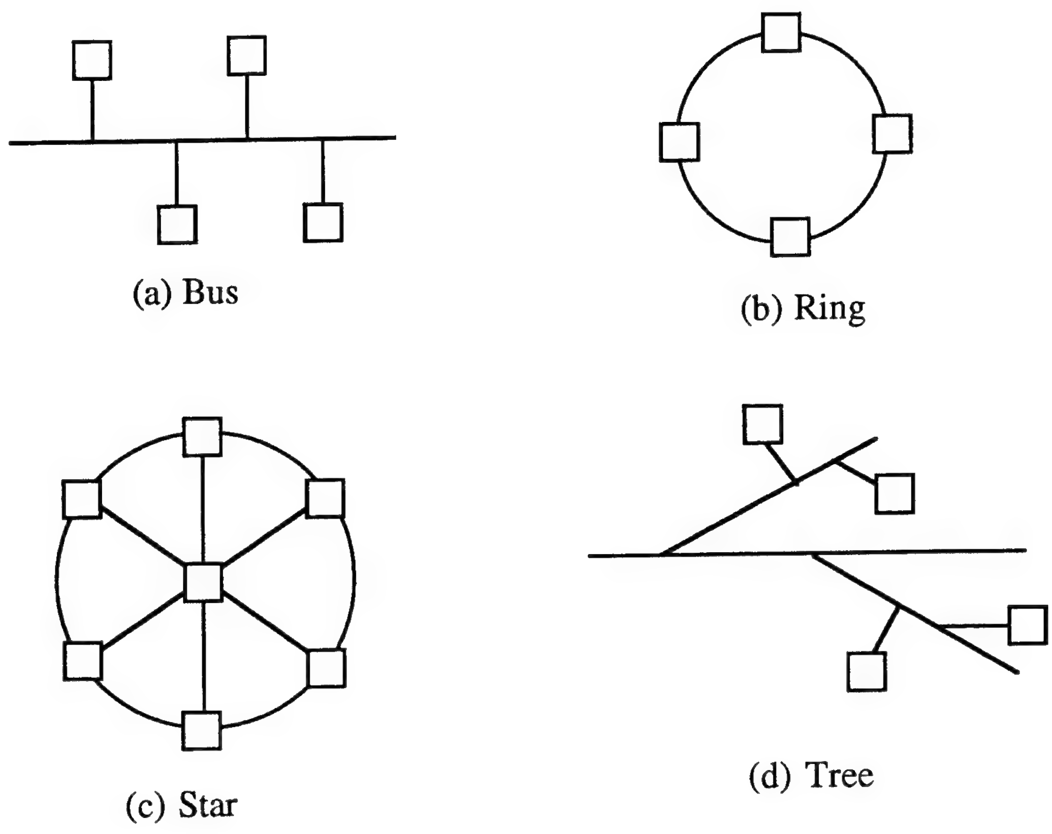


Figure 2
LAN topologies

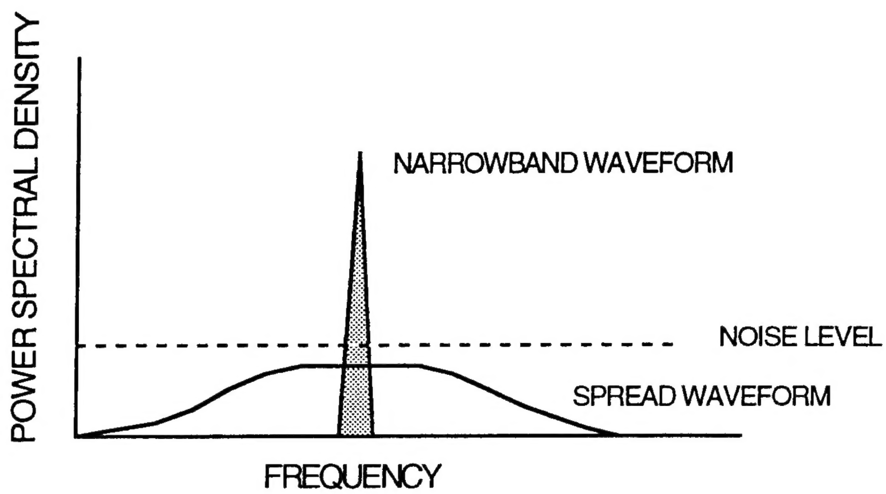


Figure 3
Comparison of narrowband signal with spread spectrum signal

## REFERENCE

1. Brewster, R. L., Data Communications and Networks, Peter Peregrinus Ltd.; London, United Kingdom, 1986.

## BIBLIOGRAPHY

1. Helmers, Scott A., Data Communications, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1989.

2. Stallings, William, Data and Computer Communications, Macmillan Publishing Company, New York, NY, 1991.

3. Tailor, Sanjay, "Wireless Communications," Technical Report ARFSD-TR-95018, ARDEC, Picatinny Arsenal, NJ, 1996.

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